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Racetrack FFAGs for medical, PRISM and energy applications

Lead Research Organisation: University of Liverpool
Department Name: Physics
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Abstract

Funding
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Fixed-field alternating gradient accelerators (FFAGs) are a hybrid between the traditional cyclotrons used early on in the history of particle accelerators, and the synchrotrons that have come to dominate the world of particle physics: CERN's Large Hadron Collider is the largest example of a proton storage ring, which is a type of synchrotron. Although they were first studied over 50 years ago in small experiments, they were initially considered too computationally complex, and early designs intended to deliver high energy particles were larger than alternative designs. However, recent advances have been made both in the radio frequency cavity technology needed to accelerate heavy particles such as protons, and in the computational tools and magnetic designs of the rings themselves. This renaissance has recently culminated in the demonstration by a Manchester-led collaboration in 2012 of the first non-scaling example of an FFAG, in an experiment called EMMA. Non-scaling FFAGs improve on their forebears by having much smaller magnets, which makes them feasible for high energy accelerators. However, the nature of the acceleration process in these rings can give rise to complex resonant effects that must be managed through careful computational design, and modern designs of the focusing and bending magnets.

EMMA demonstrated that the non-scaling principle works, but it has a highly-symmetric layout that makes

the accelerator larger than it might be. A so-called Racetrack design dispenses with this symmetry and allows a more compact design whilst increasing flexibility and space for the essential injection and extraction systems: the space is put into the racetrack sections, but is saved elsewhere. Racetrack designs can also solve some of the outstanding problems in delivering a high current of particles at high energies, as required in a number of applications. But no proper racetrack design has yet been produced that examines in detail how all the parts would fit together, and what tolerances would be needed in the magnets to allow it to work. Our proposal intends to do just that.

In this project we will look at one useful application of a racetrack FFAG, to providing sufficient energy protons (330 MeV) to allow combined patient radiotherapy treatment and imaging. This combination of treatment and imaging is not currently possible with commercial accelerators, and we think that a racetrack FFAG can made simple enough to compete with other solutions whilst delivering the proton energies required.

The lessons learned from designing this example machine will then be used to decide how best to use the racetrack FFAG principle in two other important applications. The first of these is the PRISM experiment, which seeks to measure whether muons can spontaneously transform into electrons, a method which probes the limits of the current Standard Model of Particle Physics. PRISM needs an FFAG to help clean up the muon beam before the decay experiment is performed, and a racetrack FFAG could simplify the design greatly. The second application is to help sustainable nuclear energy. A high-power particle accelerator can be used to help fast nuclear reactors dispose of current and future nuclear waste, including the UK plutonium stockpile, but current technology does not yet provide reliable enough accelerators at low cost. A non-scaling FFAG could do both, but a good method of delivering high currents in a compact accelerator has not yet been demonstrated. Again, a racetrack scheme could be used to enable this. In both these applications we will use the solution obtained in the medical study to outline schemes that could be workable. Thus, this project will try to show how the world-leading work in FFAGs recently carried out in the UK can be applied across a range of useful science and technology.

Planned Impact

This project will prepare the groundwork for the UK to become world leaders in the next generation of compact FFAG accelerators and show the feasibility of racetrack FFAGs for a wide variety of future projects. This is critical if the UK is to continue to provide scientific and innovative technical leadership in these projects. This bid requests funding to design a racetrack FFAG for medical applications and show the feasibility for energy and PRISM. Solving a common set of problems for the project areas will be highly beneficial to them all. The expected impact of this project can be split up into the following categories:

1. Specific benefits to future STFC projects:
The project is aimed at developing underpinning technology for three principle STFC project areas - medical, energy and flavour physics through the PRISM project. These are important parts of the future STFC programme with a large possibility for impact. The use of novel racetrack FFAGs for medical proton therapy could revolutionize radiotherapy; the development of accelerator driven reactors could play a key role in meeting the energy needs of the future; the PRISM experiment could make fundamental statements about the particle and symmetry content of our universe. The key observation is that these three areas all use FFAG accelerators and so have many common issues. Fundamental FFAG work in one area benefits them all. There are further possible applications in the area of neutron facilities and muon collider designs.

2. Enhancing Inter-Sectoral Collaborations:

At the highest level, the project will involve collaborations between universities and research organisations, both within the UK and internationally. All efforts will be made to ensure continual dialogues with manufacturers and users, including with hospitals such as The Christie, and with industry. This will be realised through regular workshops to present the latest research and disseminate the results. Manchester and Liverpool are core partners of a proposed STFC network for physics technologies in cancer care (Owen is on the steering committee). Through these efforts, we will generate new ideas and solutions, and foster new collaborations. We have an existing collaboration between accelerator physics and experimental particle physics within Manchester through the COMET/PRISM collaboration, which is to be a part of the consolidated grant programme for the Manchester Particle Physics Group. This close link between particle and accelerator physics in unique in the UK and essential for projects like COMET and PRISM.

3. Improving career prospects
While only one postdoc will be recruited, we expect that a number of students and collaborators will eventually be involved in this project. This will happen naturally because the investigators are all part of the Cockcroft Institute, an ongoing collaboration between the Universities of Manchester, Liverpool and Lancaster, and the Accelerator Science and Technology Centre (ASTeC). The close interaction with investigators and collaborators will provide them with expert knowledge in the field, as well as with a broad understanding of the context, at the national and international level.

4. Outreach Activities
The regular workshops mentioned above will be opened to not only collaborators, but also to potential users and researchers in other fields to generate interest in the wider research communities. Once a year, an open day will be organised at the Cockcroft Institute, to which the public will be invited. This will show exhibits (including models, posters and EMMA) and present public lectures on FFAG and its applications, and generate awareness of accelerator science and applications in the wider society. The scientific results will be disseminated to the general public.

Funded Value:

£31,857

Funded Period:

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Funder:

STFC

Project Status:

Active

Grant Category:

Research Grant

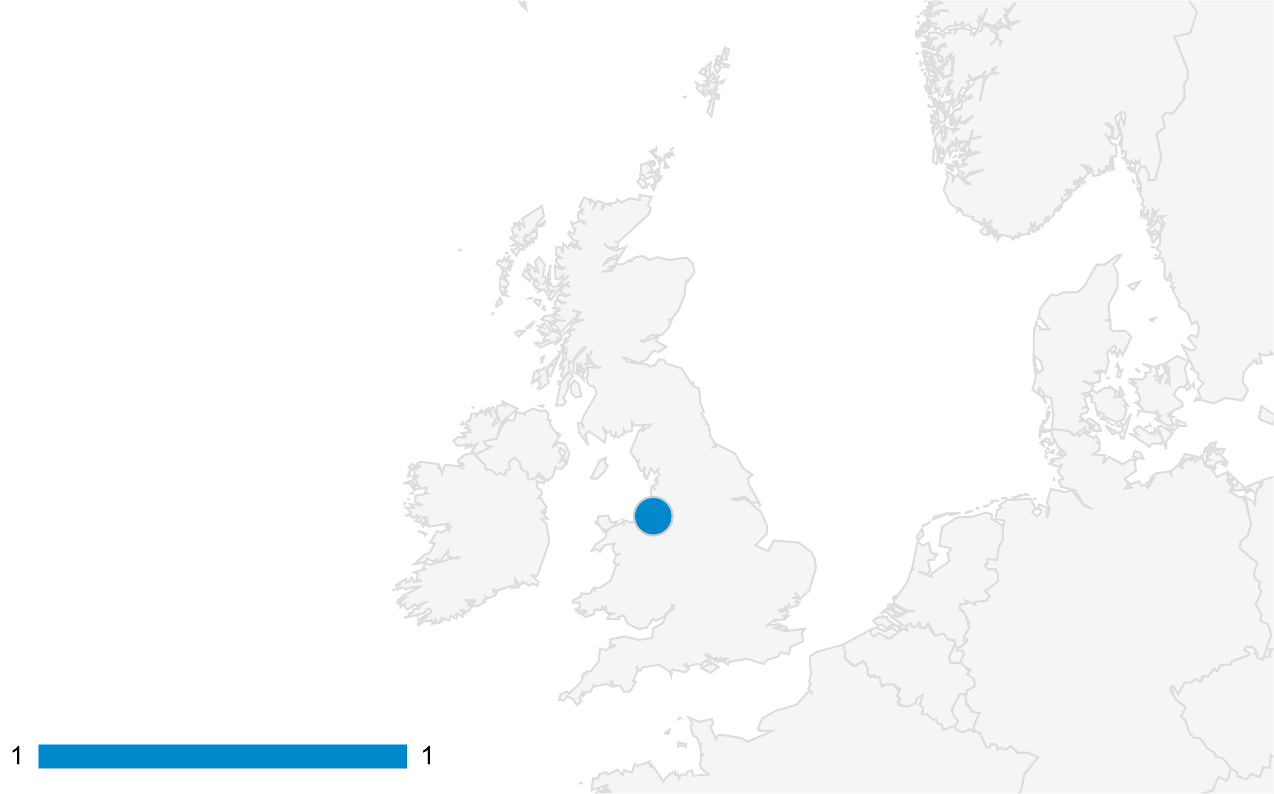
Grant Reference:

ST/K00249X/1

Principal Investigator:

Kai Meng Hock

If populated the following is a graphic depicting where in the UK the given postcode is located.



Organisations

- University of Liverpool, United Kingdom (Lead Research Organisation)

People

- Kai Meng Hock (Principal Investigator)

Publications

Data

The data on this website provides information about publications, people, organisations and outcomes relating to research projects

APIs

The data is accessible programmatically using one of three application programming interfaces GtR, GtR-2 and CERIF

Data last updated: 20 October 2013